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PLANETS SATURN AND URANUS

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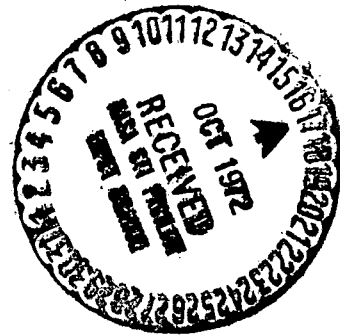
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Reduction and compilation of all brightness observations for the planets Saturn and Uranus known since 1852. It pertains nearly exclusively to estimates of degree.

The physical light variation (Figure 2, upper part) for Saturn resulting after reduction of the observed brightness to median opposition and disappearing ring (Table 1 and 2), is characterized by rounded off maxima and a pointed minimum. The amplitude has an average of $0\overset{m}{.}33$. White spots on the surface of Saturn appeared so far only during the minima.

In the case of Uranus there is a superposition of the amplitude variation of a period of 82 years with a physical light variation which follows a somewhat sinusoidal course and whose period fluctuates between 5.5 and 11.5 years (in the average 8 years). The first has an amplitude of $0\overset{m}{.}255$ and, based on the illumination theory of Seeliger, results in a flattening of $a/b = 1.16$. The physical light variation has an average amplitude of $0\overset{m}{.}29$.

Especially low minima coincide in the cases of Saturn and Uranus and occur simultaneously with a minimum of sun spots. Beyond this it is not possible to obtain any indication for a casual relationship of these two phenomena from a comparative observation of the course of the sun spot curve and the two light curves.

In the year 1933 the author made a compendium and a uniform reduction

of all brightness observations made on the planets of Mars, Jupiter, Saturn,

Uranus and Neptune which were known since 1844 and published the results at

the meetings of the Prussian Academy of Sciences (Phys.-Math. Class 1933,

XXVIII). According to these reports all five planets showed physical brightness

fluctuations besides the fluctuations caused by the increasing distances from the

Sun and the Earth, by the phase, and in case of Saturn by the inclination of the

rings, which are equivalent with fluctuation of the "reflectivity" of the "planet

surfaces" and which are of the order of magnitude $0^{m}.4$. This fluctuation in

brightness was especially distinct in the case of Saturn and in the case of Uranus.

For this reason the author observed the first continuously since 1933 and

recommended the latter to others for observation. The brightness fluctuation

of Uranus was substantially confirmed by the recently published results of

Ashbrook's[1]) observations of the brightness fluctuations of this planet. This

report deals with observations made by himself and by others and also achieved

a better overall view of the old observations made on these two planets. This

seems to be also advisable because the above-mentioned report (designated as

I throughout the text) had not been widely distributed. The brightnesses of

Saturn were improved as compared to I by the introduction of a newly derived

reduction based on a disappearing ring.

1. Saturn. The estimation of brightness was made by the author accord-

ing to the method of Argelander in correlation with at least two bright stars

without the use of optics. The fixed stars used in the various oppositions are

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[1]) Publ. Astron. Soc. Pac. 60. 116 (1948).

α Aur, α Aql, α Boo, α Lyr, α Tau, α Ori (very seldom), α CMi, β Gem,

whose brightness had been used in the system of the revised Harvard Photometry.

Extinction was considered. The accuracy of a brightness determination by

correlation with three comparative stars is of the order of magnitude of $\pm 0^m.1$

(m.F.). It seems, nevertheless, advisable to characterize the dependability

of the results by a comparison of estimates made by various observers at the

same time. Five estimates made jointly by G. Hartwig and W. Becker show

average deviations of $0^m.07$ from each other. Two joint estimates by F. Becker

and W. Becker vary in the average by $0^m.09$ from each other. A joint estimate

by K. Walter and W. Becker show only a difference in brightness of $0^m.07$.

In the above it should not be forgotten that the co-observers did not have a

special practice in the estimation of bright stars. The deviations of the occasion-

al estimations made by the above observers from the average opposition bright-

ness to be considered in each case amount to $0^m.05$, $0^m.07$, $0^m.01$, $0^m.08$, $0^m.09$,

$0^m.18$, $0^m.30$, $0^m.04$, $0^m.09$, $0^m.16$, $0^m.13$, $0^m.03$, $0^m.05$ and $0^m.05$, therefore, in

the average $0^m.09$.[2]) The average error of an individual brightness estimation

should not, therefore, be greater than $\pm 0^m.15$. Occasional larger deviations

are caused by extinction anomalies.

The reduction to average opposition was made with the distances log

$r_o = 0.980$; log $\Delta_o = 0.932$. The reduction to null phase and to disappearing

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[2]) Subsequently five additional average opposition brightnesses were
made by photometric observations by Schoenberg (photometric investigations of
Jupiter and Saturn system, Helsinki 1921) and compared with the values given
in Table 3. The differences Schoenberg minus Table 3 amount for the opposition
1916.2 + 0^m06; 1917.1 + 0^m06; 1918.2 + 0^m04; 1920.3 + 0^m01. Note that in
this case also there are only very small and apparently systematic differences
between the individual observers.'

ring were made according to the empirical reduction magnitudes given by

G. Mueller (Potsdamer Publications Nr. 8, 1893), which are given in Table 1

and 2. The phase curve of Saturn has, according to Schoenberg[1] its origin

partially in the ring and should, therefore, have a smaller phase coefficient

for a disappearing ring in contrast to Mueller's empirical finding, then given

in Table 1. Considering the uncertainties which are still existing,[2] Mueller's

values for all ring inclinations were retained. The new observations are too

inaccurate as estimates and are also distributed irregularly over the various

phases, to be considered as a contribution to the clarification of the phase curve.

The observations made at ring inclination zero do not seem to indicate that the

phase coefficient for their reduction was too large. On the other hand, the

observations at hand in conjunction with observations made previously can be

used as a test for Mueller's reduction to disappearing ring. Figure 1 shows

the average opposition brightnesses as a function of the angle of the elevation

of the Earth above the plane of the ring (B), separated for Earth in the north

(●) and Earth in the south (○). It can be seen quite clearly that the old reduction

values are still insufficient. It is peculiar that the negative B require an

opposite correction as the positive B which might indicate a small predominance

of the area brightness of the Southern Hemisphere of the planet, which is also

Table 1. Reduction to Phase Zero According to G. Mueller

Tabelle 1. Reduktion auf Phase Null nach G. MÜLLER

Phase	Reduktion	Phase	Reduktion
	m		m
0	0.000	4	−0.174
1	−0.044	5	−0.218
2	−0.087	6	−0.262
3	−0.131	7	−0.305

[1] Hdb. d. Astrophys. Bd. II, 1 S. 155 (1929).
[2] Poulkovo Obs. Circ. 26 - 27, S. 41 (1939).

faintly indicated in an area photometry by Sharnow.[1]) The improved reductions to disappearing ring which were used to make a new reduction of the old observations, are given in Table 2, column 3 and 4.

Table 2. Reduction to Disappearing Ring

Tabelle 2. Reduktion auf verschwindenden Ring

B	Red. MÜLLER	new Red. neue Red.		B	Red. MÜLLER	new Red. neue Red.	
		$B>o$	$B<o$			$B>o$	$B<o$
°	m	m	m	°	m		
0	0.000	+0.00	+0.00	15	+0.588	+0.51	+0.67
1	+0.045	0.04	0.05	16	0.621	0.54	0.71
2	0.089	0.09	0.09	17	0.652	0.56	0.75
3	0.132	0.13	0.13	18	0.682	0.59	0.78
4	0.175	0.17	0.18	19	0.712	0.61	0.82
5	0.216	0.21	0.23	20	0.741	0.63	0.86
6	0.257	0.25	0.28	21	0.769	0.65	0.89
7	0.297	0.29	0.32	22	0.797	0.66	0.93
8	0.337	0.31	0.37	23	0.823	0.68	0.96
9	0.375	0.34	0.41	24	0.849	0.70	1.00
10	0.413	0.38	0.46	25	0.873	0.72	1.03
11	0.450	0.41	0.50	26	0.897	0.74	1.06
12	0.486	0.44	0.55	27	0.920	0.75	1.09
13	0.521	0.47	0.59	28	0.943	0.77	1.12
14	0.555	0.50	0.63				

The _physical light variation_ of Saturn which remained after the reduction to average opposition, phase zero and disappearing ring, is shown in the upper part of Figure 2 based on the total observation material given in Table 3. It maintained essentially the same character since 1858, that is, maxima which were flat and rounded off were interrupted at irregular intervals by more pointed minima. The extreme values of brightnesses are (if the two isolated values of 1891.2 and 1903.9 are not included), 0^m64 at the absolute maximum (1936.0) and 1^m24 in the absolute minimum (1866.5). If, on the other hand, the amplitude is defined as the difference of brightness between a maximum and the following minimum, smaller values than 0^m60 are found throughout (Tab. 4).

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[1]) See also: Wirtz, Astron. Nachr. 210. 113 (1920) and 218. 17 (1923).

Abb. 1. Restlicher Gang der mittleren Oppositionshelligkeiten
von Saturn mit dem Elevationswinkel *B* der Erde über der
Ringebene (● Erde nördlich, ○ Erde südlich) nach Berück-
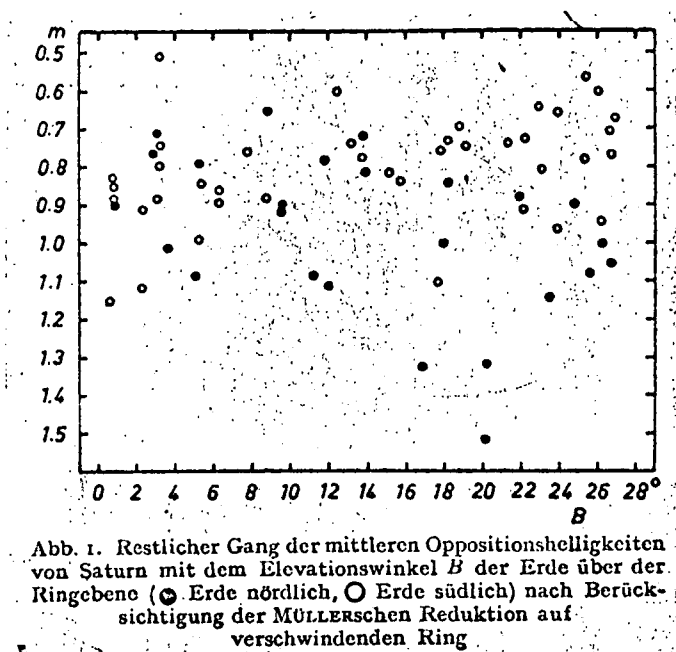sichtigung der MÜLLERschen Reduktion auf
verschwindenden Ring

Fig. 1. Remaining course of average opposition brightnesses of Saturn with the angle of elevation B of the Earth above the plane of the ring (● Earth in the north, ○ Earth in the south) after taking into account Mueller's reduction to disappearing ring.

The average brightness of the maximum is 0^m73, and of the minimum 1^m06. The values for maximum brightnesses scatter much less than the values for the corresponding minima. The value for the average median opposition brightness can remain at 0^m90 as described in (I).

Occasionally there occur sudden changes in the brightness of Saturn, just as they had been observed at other planets especially in the case of Uranus and Jupiter (in parts also photoelectric) (see I). The following tabulation illustrates such sudden changes as made in more recent observations:

1938, Sept. 15 till 1938, Oct. 24: $0^m98 \pm 0^m02$	Discontinuity -0^m19 $\pm 0^m03$	
1938, Nov. 24 till 1939, Jan. 20: 0.79 ± 0.02		
1944, Sept. 27 till 1945, Feb. 11: 1.19 ± 0.05	Discontinuity -0.18 ± 0.06	
1945, Mar. 1 till 1945, Apr. 7: 1.01 ± 0.04		

Both discontinuities occurred at the beginning of the increasing branch of the light curve and continued in the sense of an increase in brightness.
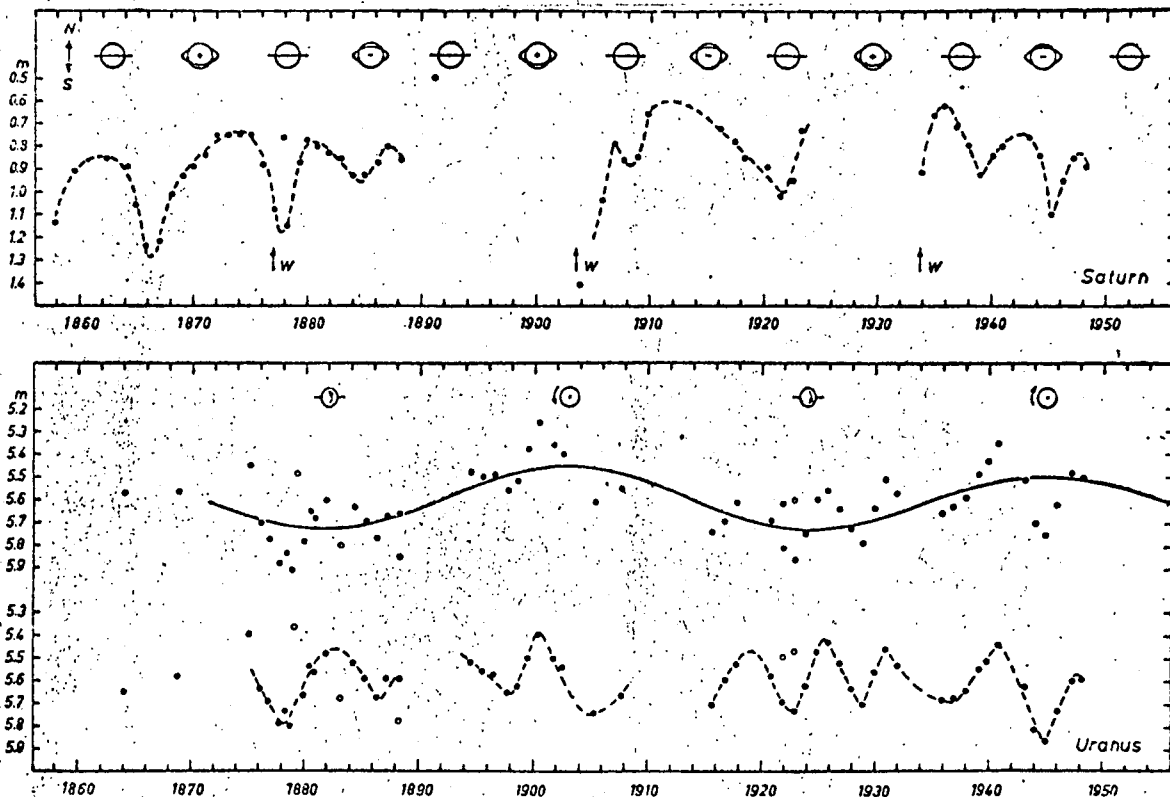
Abb. 2. Oben: Mittlere Oppositionshelligkeiten von Saturn nach Reduktion auf verschwindenden Ring. Der Wert für 1878 ist unsicher. Oberhalb der Lichtkurve ist die jeweilige Ringneigung in ihren Extremstellungen angedeutet. Unten: Beobachtete Lichtkurve von Uranus mit dem eingezeichneten Abplattungslichtwechsel. Oberhalb der Licht-kurve ist die jeweilige Stellung der Rotationsachse des Planeten in ihren extremen Lagen angedeutet. Die untere Kurve zeigt den vom Abplattungslichtwechsel befreiten physischen Lichtwechsel des Uranus. Abweichende Werte sind als offene Kreise gezeichnet.

Fig. 2. Top: Average opposition brightness of Saturn after reduction to disappearing ring. The value for 1878 is uncertain. The corresponding ring inclination is indicated above the light curve in its extreme position.

Bottom: Observe light curve of Uranus with the marked in change in flattening. The corresponding position of the axis of rotation of the planet is indicated in its extreme positions. The lower curve shows the physical light variation of Uranus without the influence of the changes in flattening. Deviating values are designated as open circles.

Table 3. Average opposition brightnesses of Saturn for disappearing ring and phase 0° (System of the Revised Harvard Photometry)
M = measurement   S = estimate

Tabelle 3. Mittlere Oppositions-Helligkeiten des Saturn für verschwindenden Ring und Phase 0° (System der Revised Harvard Photometry)
M = Messung, S = Schätzung.

Epoch Epoche	Brightness Hell. (m)	m. F. (m)	n	Method Meth.	Source Quelle	Epoch Epoche	Brightness Hell. (m)	m. F. (m)	n	Method Meth.	Source Quelle
1852.4	1.20	±0.04	3	M	1	1870.5 / 1871.5	0.84	±0.03	40	S	3
1857.8	1.14	3	5	M	1	1871.5 / 1872.5	0.75	4	27	S	3
1858.9 / 1860.2	0.91	4	24	S	3	1872.5 / 1873.5	0.75	3	43	S	3
1860.2 / 1864.5	0.84	2	80	S	3	1873.5 / 1874.5	0.75	4	32	S	3
1862.4	0.88	2	7	M	2	1874.5 / 1875.6	0.75	3	39	S	3
1863.4 / 1865.0	0.89	2	7	M	2	1875.6 / 1876.6	0.88	3	45	S	3
1864.5 / 1865.3	1.06	2	116	S	3	1876.6 / 1877.7	1.08	4	26	S	3
1865.3 / 1866.4	1.24	2	73	S	3	1877.7 / 1878.8	1.15	4	29	S	3
1866.4 / 1867.5	1.22	3	52	S	3	1877.9	(0.76)	4	6	M	4
1867.5 / 1868.5	1.01	3	53	S	3	1879.2	0.87	3	61	S, M	3.4
1868.5 / 1869.5	0.93	3	56	S	3	1879.9	0.77	1	47	M	4
1869.5 / 1870.5	0.89	3	56	S	3	1880.9	0.80	2	26	M	4
						1881.9	0.83	2	17	M	4

Epoch Epoche	Brightness Hell. (m)	m. F. (m)	n	Method Meth.	Source Quelle	Epoch Epoche	Brightness Hell. (m)	m. F. (m)	n	Method Meth.	Source Quelle
1883.0	0.85	±0.03	9	M	4	1922.4	0.95	±0.02	68	M, S	10, 13
1884.0	0.93	2	17	M	4	1923.2	0.73	3	10	M	10
1884.9	0.93	1	37	M	4	1933.8	0.91	4	9	S	28
1886.1	0.87	2	24	M	4	1934.8	0.66	2	9	S	28
1887.1	0.80	3	14	M	4	1935.8	0.62	1	4	S	28
1888.2	0.86	3	12	M	4	1936.8	0.71	2	5	S	28
1891.1	0.50	3	12	M	4	1937.9	0.79	3	9	S	28
1903.8	1.41	8	3	S	13	1938.9	0.92	4	19	S	28
1905.8	1.04	10	30	S	13	1940.0	0.84	4	21	S	28
1906.8	0.79	11	46	S	13	1940.9	0.80	4	15	S	28
1907.7	0.86	4	72	S	13, 14	1941.8	1.10	9	4	S	28
1908.8	0.85	4	21	S	13	1943.3	0.76	6	3	S	28
1909.8	0.66	3	31	M	8	1944.1	0.84	2	9	S	28
1916.1	0.72	3	14	M	9	1945.1	1.10	4	11	S	28
1917.3	0.78	4	4	M	9	1946.2	0.95	2	9	S	28
1918.2	0.85	2	17	M	9	1947.1	0.85	3	14	S	28
1920.2	0.89	2	42	M, S	10, 13	1948.2	0.89	2	14	S	28
1921.4	1.02	2	111	M, S	10, 13						

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Table 4. Extreme Values of the Bright-
ness of Saturn

Tabelle 4. Extremwerte der Saturn-Helligkeit

Maximum		Minimum		Amplitude
	^{m}		^{m}	^{m}
1862.0	0.85	1866.5	1.24	0.39
1874.0	0.74	1877.5	1.15	0.41
1881.0	0.77	1885.0	0.93	0.26
1909.8	<0.66	1921.5	1.02	0.36
1936.0	0.62	1939.0	0.92	0.30
1947.0	~0.76	1945.2	1.10	0.34
Mittel	0^m73		1^m06	0^m33
Streuung	$\pm0^m08$		$\pm0^m13$	$\pm0^m05$

Here again we would like to point out the circumstance which could be of special significance for the interpretation of brightness fluctuations: the occurrence of conspicuous white spots on the planetary disc at several minima. Such spots appear very suddenly 1877.0, 1903.5 and 1933.7 (W in Fig. 2). The fact that they were always very short lived agrees with the short duration of the corresponding minima. No white spots have been observed up-to-date within the region of a brightness maximum, which is not surprising when considering the higher area brightness area of the planetary disc at this point.

The coincidence of the white spots with the minima motivated the author (I) to the conclusion that the planet covered itself beginning with the maximum slowly with an increasingly dense layer of decreasing "reflectivity" which may tear apart during its phase of highest development during a minimum, so that the openings created by this make it possible that the brighter original surface

layers which lie below it, reappear (white spots). This event then usually introduces the subsequent fairly rapid disillusion of the dark layer, at which occasion the brightness again approaches at maximum.

2. Uranus. In the case of the planet Uranus a variation of light occurs during its median opposition brightness, which has two reasons. One reason is the flattening of the planetary body (ratio of axes approximately 9:10), which causes a variation of light during its period of rotation (84 years) in conjunction with the increased inclination of the axis of rotation toward the rotational plane (approximately 90°). The other reason is fluctuations of the "reflectivity" of the "planetary surface" which cause in relatively regular intervals of approximately 6 to 8 years maxima and minima of the brightness, at an amplitude of approximately $0^{m}_{.}30$ (see I).

Since the report (I) median opposition brightnesses ($\log r_0 = 1.284$; $\log \Delta_0 = 1.261$) for additional 12 oppositions became known and were reported by the observers Ashbrook, Fedtke, Lause and Malsch. These data were re-calculated by the author according to the System of Revised Harvard Photometry[1]) and are given in Table 4 together with previous observations.

The light variation induced by flattening is shown in Fig. 2 (Uranus, upper curve). In this instance the maxima occur when the pole is turned toward the Earth, the minima when the Earth is in the equatorial plane of the planet, since at this time the area of the planetary disc is at minimum. The corresponding data are:

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[1]) The author expresses his gratitude to the observer for the conversion calculation of the observations made by Ashbrook.

Maximum 1903: $5\overset{m}{.}45$; Minimum 1882: $5\overset{m}{.}73$; Amplitude $0\overset{m}{.}28$.
Maximum 1945: 5.50; Minimum 1924: 5.73; Amplitude 0.23.

Both minima which were observed up-to-date have the same brightness.

Because of the rotation of the planet this is not to be expected otherwise even

for the varying distribution of brightness on the planetary surface. On the

other hand, the brightnesses of both maxima differ by $0\overset{m}{.}05$. From this it

can be concluded that the polar surface of the planet which was turned towards

the Earth in 1903 has a higher area brightness than the other polar surface

in the year 1945. Only observations of later maxima can decide whether this

difference is a permanent phenomenon. The ratio of the axes of the planetary

disc a/b can be calculated from the average amplitude of the light variation

caused by flattening of $0\overset{m}{.}255$ according to the theory of Seeliger.[1] Depending

on whether Lambert's or Lommel and Seeliger's law of reflection is used,

we have

$$Q_L = 2 \pi a^2 \, \Gamma \, (P \cos^2 A + R \sin^2 A) \text{ (Lambert)}$$

or

$$Q_{LS} = \frac{\pi \, a \, b \, \Gamma}{2} \sqrt{I + \frac{a^2 - b^2}{b^2} \sin^2 A} \text{ (Lommel-Seeliger),}$$

where Q is the quantity of light reaching the Earth from the planet, A is the

angle of the elevation of the Earth above the equator of Uranus (during maxi-

mum brightness A = 90°, during a minimum, on the other hand, A = 0°),

P and R are two magnitudes depending on the degree of flattening and tabu-

lated by Seeliger and Γ is a constant. The two values are obtained[2]

$$\frac{a}{b} = 1.16 \text{ (Lambert; } \frac{a}{b} = 1.26 \text{ (Lommel-Seeliger).}$$

[1] Abh. d. K. bayer, Akad. d. Wiss. II cl. XVI, Bd. II, 1887.

[2] See also K. Wirtz, Astron. Nachr. 227.273 (1926), where the flat-
tening derived from the brightnesses up to then were found to be somewhat
smaller.

The first value agrees well with the results of repeated but very difficult

micrometer measurements, which gave an average value of approximately

$\frac{a}{b} = 1.1$.

Table 5. Average Opposition Brightnesses of Uranus for Phase 0
(System of Revised Harvard-Photometry)
S = estimate   M = measurement

Tabelle 5. Mittlere Oppositions-Helligkeiten des Uranus für Phase Null
(System der Revised Harvard-Photometry)
S = Schätzung; M = Messung

Epoch Epoche	Brightness Hell.	m. F.	n	Method Meth.	Observation Beob.	Epoch Epoche	Brightness Hell.	m. F.	n	Method Meth.	Observation Beob.
	m						m	m			
1864.–	5.57	—	4	M	2	1901.7	5.36	±0.07	4	S	17
1868.8	5.56	—	1	S	3	1902.5	5.40	8	3	S	17
1874.4 / 1875.9	5.45	±0.10	5	S	3	1905.4	5.61	4	10	S	13
						1907.7	5.55	—	—	S	22
1875.9 / 1876.3	5.70	4	20	S	3	1915.6	5.74	3	36	S	23
						1916.7	5.69	0	1)	S, M, S	23, 24, 25
1876.3 / 1877.2	5.77	4	28	S	3	1917.8	5.61	3	44	S	23, 25
						1920.9	5.69	1	36	S	26
1877.2 / 1878.3	5.88	4	30	S	3	1921.9	5.81	2	28	S	26
1878.3	5.83	2	10	M	4	1921.9	(5.61)	1	47	S	13
1878.3 / 1879.3	5.91	4	28	S	3	1922.9	(5.60)	1	63	S	13
1879.2	(5.48)	—	4	M	4	1922.9	5.86	2	>24	S	26,27
1879.3 / 1880.3	5.78	4	26	S	3	1923.9	5.75	1	121	S	13, 26, 27
						1924.9	5.60	2	56	S	26,27
1880.6	5.65	2	30	S, M	3, 4	1925.9	5.56	2	87	S	26,27
1880.4	5.68	—	5	M	5	1926.8	5.64	2	56	S	26,27
1881.7	5.60	3	53	S, M	3,4,5	1927.9	5.73	1	115	S	26
1882.3	5.62	2	14	S	15	1928.9	5.79	1	52	S	26
1883.1	(5.80)	2	5	S	15	1929.9	5.64	2	33	S	26
1884.3	5.63	2	24	M	4	1930.9	5.51	2	17	S	26
1885.3	5.69	2	17	M	4	1931.9	5.57	1	7	S	26
1886.3	5.77	2	12	M	4	1935.9	5.66	2	60	S	29,31
1887.2	5.67	5	3	S	15	1936.9	5.63	2	43	S	30,31
1888.3	5.66	3	18	M, S	4, 15	1938.0	5.59	3	22	S	29
1888.3	(5.85)	—	1	M	5	1939.0	5.49	2	24	S	30
1894.5	5.48	—	15	M	5	1939.7	5.43	—	3	S	31
1895.5	5.50	—	9	M	5	1940.8	5.35	5	10	S	31
1896.5	5.49	—	15	M	5	1943.2	5.51	6	4	S	31
1897.7	5.56	—	20	M	5	1944.0	5.70	3	20	S	31
1898.6	5.52	—	42	M	5	1944.9	5.75	2	38	S	31
1899.5	5.38	4	14	S	17	1945.9	5.62	5	4	S	31
1900.4	5.26	7	4	S	17	1947.1	5.48	6	6	S	31
						1948.1	5.50	3	—	S	32

1) 2916 Beobachtungen, davon 2100 von Beob. 24.

1) 2916 observations among these 2100 by observer 24.
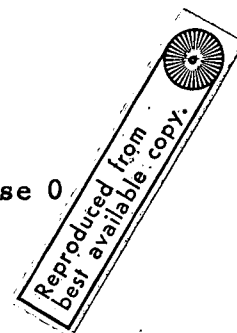
If we eliminate the sinusoid light variation induced by flattening

(taking consideration of the different heights of the two maxima), a nearly

periodic and sinusoid variation in light becomes distinctly apparent, from

which we can conclude to variations in the "reflectivity" of the "planetary

surface." It is represented in the lower part of Figure 2. In 5 of the 53

observed oppositions, the brightnesses given by one individual observer

are outside of the context. These are designated in the Figure as open

circles. Among these the value given by Pickering from 1888.3 is without

significance since it is based on only a single observation. Mueller's value

of 1879.2 is designated as unreliable by the observer himself since glass

screens were used for the measurement whose attenuation was not accurately

known. Plassmann's value of 1883.1 is based on 5 estimates which cannot

be used to obtain a reliable average value in spite of their very small average

error. The two brightnesses given by Wirtz of 1921.9 and 1922.9 which are

based on graduated estimates contradicts to numerous and very reliable

observations made at the same time by three other observers. The brightness

of 1923.9 given by Wirtz which was obtained in the same manner as during

the two preceding oppositions, agrees with the observations made simultaneously

by the two above-mentioned observers. An explanation could be given by the

assumption that this is a case of systematic differences in observation which

we cannot explain since Wirtz did not continue his measurements. From this

it becomes quite clear that only more prolonged series of observations can

actually make valuable contributions to the question of the physical light variation

of the planets.

The maxima and minima observed up till now for Uranus are given with their intermediate periods in Table 6.

The absolute extreme values of the average opposition brightnesses are 5^m39 (1900.5) and 5^m86 (1945). The scattering of the maxima around the average value is confined within much narrower limits than the scattering of the minima. In this respect the circumstances are the same as for Saturn. The average median opposition brightness of 5^m58 given in (I) is not influenced by the newly added observations. The average intermediate period between the maxima and the minima is 8 years, varying between 5.5 to 11.5 years.

Table 6. Extreme Brightness Values for Uranus

Maxima		Intermediate Period	Minima		Intermediate Period
~1874	--	9 years	1878.5	5^m78	8 years
1883	~5^m45	8 "	1886.5	5.67	11.5 "
~1891	--	9.5 "	1898	5.65	7 "
1900.5	5.39	(18.5)"	1905	5.74	10 "
1919	~5.47	6.5 "	~1915	~5.75	8 "
1925.5	5.42	5.5 "	1922.8	5.73	6 "
1931	5.46	10 "	1929	5.70	7 "
1941	5.44		1936	5.68	9 "
Average:	5^m44	8.4 years	1945	5.86	
Scattering:	$\pm 0^m03$		Average:	5^m73	7.4 years
			Scattering:	$\pm 0^m06$	

Average Amplitude: $5^m73 - 5\ 44 = 0^m29$.

Tabelle 6. Extremwerte der Uranus-Helligkeit

Maxima		Zwischen-zeit	Minima		Zwischen-zeit
~1874	—	9 Jahre	1878.5	5^m78	8 Jahre
1883	~5^m45	8 ,,	1886.5	5.67	11.5 ,,
~1891	—	9.5 ,,	1898	5.65	7 ,,
1900.5	5.39	(18.5) ,,	1905	5.74	10 ,,
1919	~5.47	6.5 ,,	~1915	~5.75	8 ,,
1925.5	5.42	5.5 ,,	1922.8	5.73	6 ,,
1931	5.46	10 ,,	1929	5.70	7 ,,
1941	5.44		1936	5.68	9 ,,
Mittel:	5^m44	8.4 Jahre	1945	5.86	
Streuung:	$\pm 0^m03$		Mittel:	5^m73	7.4 Jahre
			Streuung:	$\pm 0^m06$	

Mittlere Amplitude: $5^m73 - 5^m44 = 0^m29$.

3. <u>Comparison of Light Curves.</u> In view of the physical brightness

fluctuations of Uranus (added to the "short-term" fluctuations considered here

are according to (I) many sudden fluctuations of the average magnitude of

$0^{m}.15$), this planet would seem to be a rather problematical object for investi-

gating the constancy of solar radiation. On the other hand, it is a question

of considerable interest whether there is any kind of a relationship between

the brightness fluctuations of the planets and the <u>sun spot cycle</u> or any other

periodicity in solar radiation. Because of the infrequent coincidence of the

minima of different planets we were (I) of the opinion that the sun cannot be

considered as a factor promoting scattering of the brightness fluctuations.

The light curve which we now obtain from Saturn and Uranus seem to indicate

that this opinion should be restricted because some minima (which are in this

case much more important than the maxima which probably rather characterize

the "normal state" because of their restricted scattering) occur with a fairly

high degree of accuracy during the same epoch. This might become apparent

from the following:

	Minima	
Saturn	Uranus	Time Difference
1857.5	no observation	----
1866.5	no observation	----
1877.5	1878.5	1 year
1885.0	1886.5	1.5 year
no observation	1898	----
1904	~1904/05	~0.5 year
near maximum	~1915	no coincidence
1921.5	1922.8	1.3 year
no observation	1929	----
1933.5	no observation	----
1939	average brightness	no coincidence
1945	1945	0

Minima

Saturn	Uranus	Zeitdifferenz
1857.5	keine Beob.	—
1866.5	keine Beob.	—
1877.5	1878.5	1 Jahr
1885.0	1886.5	1.5 Jahre
keine Beob.	1898	—
1904	~1904/05	~0.5 Jahre
nahe Max.	~1915	keine Koinzidenz
1921.5	1922.8	1.3 Jahre
keine Beob.	1929	—
1933.5	keine Beob.	—
1939	mittl. Hell.	keine Koinzidenz
1945	1945	0

Among the 7 minima which were observed for both planets 5 coincide within 1.5 years. Two of them show no coincidence. It is significant that the closest coincidence occurs for the lowest minima of both planets. The most important reason for the continuation of brightness observation seems to be to further investigate the question of these coincidences.

Since, within certain limits a synchronism of the brightness variation cannot be rejected, it seems to be worthwhile to investigate solar cycles in parallel with brightness fluctuations. The only known cycle among these is the cycle of sun spots covering a period from 1858 up to the present. A cursory observation already shows that if there is any correlation at all, it could be only between the minima of the light curves and the spot curves on the one side and between the maxima of the light curves and spot curves on the other side.

The following compilation gives an overall view of the coincidences of the minima.

Minima

Sun Spots	Saturn	Uranus	Coincidence
1855.5	1857.5	no observation	average
1866.6	1866.5 (t)	no observation	good (Saturn)
1878.4 (b)	1877.5 (t)	1878.5 (t)	good (Saturn, Uranus)
1889.0 (b)	1885.0 (s)	1886.5	none
no minimum	no observation	1898	none
1901.1 (b)	1904 (t)	1904/05 (t)	none
1913.0 (b)	no observation	~1915	average (?)
1923.5	1921.5 (t)	1922.8	good (Uranus)
no minimum	no observation	1929	none
1933.7	1933.5	no observation	good (Saturn)
no minimum	1939	average brightness	none
1944.1	1945 (t)	1945 (t)	good (Saturn, Uranus)

(b) wide minima, (s) poorly defined minima, (t) deep minima.

Minima

Sonnenflecken	Saturn	Uranus	Koinzidenz
1855.5	1857.5	keine Beob.	mittelgut
1866.6	1866.5 (t)	keine Beob.	gut (Saturn)
1878.4 (b)	1877.5 (t)	1878.5 (t)	gut (Saturn, Uranus)
1889.0 (b)	1885.0 (s)	1886.5	keine
kein Min.	keine Beob.	1898	keine
1901.1 (b)	1904 (t)	1904/05 (t)	keine
1913.0 (b)	keine Beob.	~1915	mittelgut (?)
1923.5	1921.5 (t)	1922.8	gut (Uranus)
kein Min.	keine Beob.	1929	keine
1933.7	1933.5	keine Beob.	gut (Saturn)
kein Min.	1939	mittlere Helligk.	keine
1944.1	1945 (t)	1945 (t)	gut (Saturn, Uranus)

(b) breite Minima, (s) schwach ausgeprägte Minima, (t) tiefe Minima.

From 22 cases, 5 gave a good coincidence, 2 an average coincidence, among which the coincidence of 1913.0 could possibly be considered as good, if the minimum for Uranus (approximately 1915) would be better defined.

Five minima for the planets have no corresponding partner in the spot curve. The circumstance is of significance that the deep minima on the light curve results in better coincidences as the poorly defined or average minima. Since, on the other hand, the minima for the spot curves are much wider than the minima for the two light curves, it is difficult to arrive at a convincing decision

of an actual causative correlation.   The coincidence of the maxima is not as

good and for this reason we shall not discuss it here any further.

A continuation of the brightness observations on Saturn are required

because it is necessary to further investigate the coincidence of white spots

with the minima and because of the epoch of future maxima and minima has

to be established at the right time so that they can be observed spectro-

graphically.   Because the change of the "reflectivity" is probably only the

visible expression of physical processes occurring in the planetary atmosphere

which can be identified by the intensity ratios of spectro-bands.   We are sorry

to say that there are up to the present no usable spectro of Saturn available

which could be used in connection with the light variations, and especially

that the light spot of 1933.7 has not been utilized by anybody for spectro-

graphic observations.

A continuation of the brightness observations of Uranus are doubtlessly

desirable.   The light variation caused by flattening had not yet been investi-

gated over the full period of 84 years.   Each polar region should be observed

at least twice in order to check the constancy of its "reflectivity."   The "short-

term" light variation should, therefore, be further pursued, so that the phase

of the light variation will be known for future spectrographic observations.

The author expresses his gratitude to Dr. Ashbrook for stimulating

correspondence on the subject treated in this report.